Sub-15 nm Spatial Resolution Soft X-ray Microscopy

A New Tool for Nanoscience

Researchers in LBNL's Center for X-ray Optics (CXRO) have achieved a breakthrough in x-ray based microscopy by demonstrating sub-15 nm spatial resolution. This makes possible X-ray microscopy a) in a mode that it is sensitive to elements such as C, N, O, Al, Ti, Fe, Co, Ni; b) in studies in a wide variety of scientific disciplines from magnetism to biological imaging; and c) in studies of wet environmental samples. Extension to sub-10 nm resolution is expected.

Nanoscience and nanotechnology require analytic tools with spatial resolution at the nanoscale. Also, for many studies in the life and physical sciences it is desirable, if not critical, to have tools that permit elemental and chemical identification on a spatial scale of 10 nm or better. X-ray based microscopy, using transmission zone plates as focusing elements, can provide this degree of spatial resolution, but only if very precise optics can be fabricated. To achieve 15 nm resolution for example, zone plates must be made with a placement accuracy of 5 nm.

Electron-beam lithography is used to make the zone plates but the narrow linewidths required cannot be achieved with standard techniques because beam broadening, resulting from electron scattering within the recording medium (resist), leads to a loss of image contrast and thus printability for dense features. To overcome these limitations, the CXRO researchers developed a new technique in which only semi-isolated features are written. In this technique, the dense zone plate pattern is sub-divided into two less dense, complementary patterns, which are fabricated separately and then overlaid (using techniques developed at LBNL for the nanowriter electron beam system), with high accuracy to yield the desired pattern (see figure), in this case plates with 15 nm outer zone width with better than 2 nm accuracy. After installation of the zone plates into the XM-1 microscope at the Advanced Light Source (ALS), the sub-15 nm resolution was confirmed by imaging test objects. As shown in the figure, a line pattern of chrome and silicon with a 15nm half pitch is clearly resolved.

There are more than thirty synchrotron facilities worldwide. Furthermore, it is anticipated that compact soft x-ray sources will also be available in the not too distant future, using laser-produced plasmas, femtosecond laser high harmonic techniques, or EUV/soft x-ray lasers. With the advances described here, a wider use of zone plate based soft x-ray microscopy across the broad range of nanoscience and nanotechnology is predicted. As an example of the power of the technique, these plates have been used in the XM-1 microscope to make three-dimensional images of cryogenically fixed cells by using computer aided tomographic (CAT-scan) reconstructions.

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